A Heuristic Approach Based on the Ant Colony Optimization for the Routes Elaboration on the Fuel Collection for the Brazilian Petrolium Agency

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***Abstract* - The trade of petrol derivatives such as natural gas and biofuel is an activity that demands supervision and monitoring. The ANP (Petrol, Natural Gas and Biofuel Brazilian Agency) is responsible for guaranteeing the quality of the products made by the petrol industry. Nevertheless, in order to be efficient, the ANP has established a partnership that authorizes the LAPQAP/ UFMA (Analysis and Research in Petrol Analytical Chemistry Laboratory/Federal University of Maranhão) to be its representative in the State of Maranhão. The proposal of this research is to present a prototype in order to automatize part of the fuel sample's collection process in order to make the tasks simpler, which nowadays are executed by the lab's analysts, who make that work by their experiences, increasing the number of supervised fuel stations aiming to diminish the irregularities on fuels traded in the State of Maranhão. Developed the prototype called S-Rota that is responsible for creating a circuit between the starting point UFMA and the fuel stations that approaches the concepts regarding the Ant Colony Optimization Algorithm (ACO).**

Keywords - Collection; Monitoring; Quality; Fuel; ANP; ACO.

I. INTRODUCTION

The ANP is responsible for the execution of the national policy for the Petrol, Natural Gas and Biofuel Power Sector according to the Petrol Law (Law number 9.478 / 1997). To make these actions concrete, the ANP has developed a Fuel Quality's Monitoring Program (PMQC) and established a representative in each state.

The PMQC has as objective to systematically evaluate the quality of the fuel traded in Brazil (Gas, Diesel, Ethanol and B2 mix) mapping situations that are good enough according to its parameters so that supervising actions can be directed. The PMQC has 23 partner laboratories.

In State of Maranhão, the Federal University of Maranhão with its Analysis and Research in Petrol Analytical Chemistry Laboratory (LAPQAP / UFMA) is responsible by the PMQC – ANP in monitoring the fuel's quality in Maranhão State, as well as sending Brazilian Automobiles Liquid Fuels' Quality monthly reports to ANP.

Thus, the program developed by the ANP, the PMQC needs to be analyzed, identified and characterized in its main stages so that it can be contextualized to Maranhão's scenery. Afterwards, it is observed the Fuel Sample's Collection (CAC) and its relationship with the other stages executed by the LAPQAP.

At the Fuel Sample's Collection stage, the LAPQAP focus on evaluating the costs and time spent for the inspected fuel stations definition, routes creation and samples' collection. These days, the elaboration of the definition of the fuel stations inspected and the route creation is handmade. This action puts all the responsibility on the collectors (driver and analyst). This stage is fundamental because it influences the conclusion of all the other stages of PMQC and is subject to human mistakes.

The developed prototype elaborates the better route between the LAPQAP and the reseller fuel stations, having this approach based on the Ant Colony Optimization [1].

II. PMQC

The PMQC concept is to ascertain the quality's standard of the traded fuel on its extraction, refining, distribution and reselling stages to the national market [2]. PMQC's main objectives are surveying the general indicators of the fuel's quality traded in the country and the identification of non-conformities focus, aiming to orientate and improve the Agency's inspection area performance [2].

A. *PMQC stages*

The three stages that compound PMQC are:

- Fuel Samples' Collection: The first stage is based on the accomplishment of raffles that indicates the stations that will be inspected and the fuel samples' collection by the LAPQAP.
- Samples' Lab Analysis: The second stage is responsible for collecting the samples that are conforming the ANP regulation and analyze their quality.
- Data Treatment and Information sending to ANP: This stage finds the result generated on the second stage to organize and insert them on the system of Fuel's Quality Monitoring (MQC) to send them to ANP after all.

B. *Fuel Samples' Collection Stage (CAC)*

This work objective is focused on this stage, aiming to automatize part of the collection process. In State of Maranhão, the existing fuel stations (can be called universe) is saved on the data base lab which represents the ANP in the State.

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Besides that, aiming to make the logistics easier, the Maranhão State is divided in four regions by the LAPQAP called R1, R2, R3 and R4, as shown in Figure 1. This way, the laboratory has one week to collect the samples in each region.

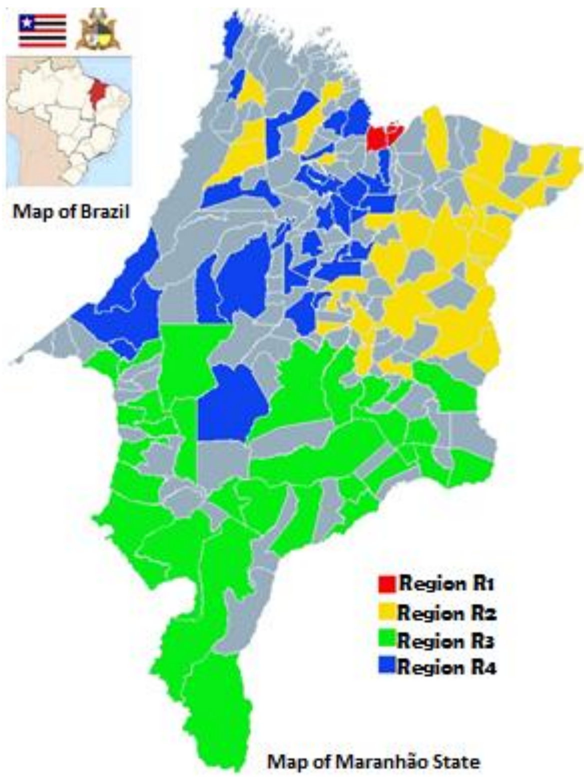

Figure 1. Four Regions [1].

The first week of the month is destined to the region R1 (Saint Louis city), so, the initial task is to make 10% (ten percent) of the fuel station in the group of towns of R1. The same thing happens in the others regions, even though needs to be kept the second week to R2, the third one to R3 and the forth one to R4 .

The sampling in this work focus in the region 1, considering no have differences in generation routes among the regions.

Then, when the fuel stations to be inspected are defined, the responsible collaborator will have the route between the starting point – UFMA and the fuel stations.

The routes nowadays are done without the help of any tools and/or logistical techniques, only the collaborator's empirical knowledge, even though the LAPQAP establish some criteria to prioritize some fuel stations above others.

The main criteria are divided in:

- Fuel's Quality.
- Documentation.
- Distance.

For the fuel's quality criteria, the last sample of the three types of fuel: alcohol, gas and diesel. According to the result of each type of fuel, a level of priority is established.

For the documentation criteria, the LAPQAP requires the inspected level to present the documentation required by the ANP. Then, the laboratory elaborates a list that discriminates and informs the situation of each document.

For the distance criterion, the region to be inspected is verified and the shortest distance between the starting point and the fuel stations are is analyzed. In other words, the closest fuel stations to the starting point are prioritized. After this, the analyst evaluates the three criteria and defines the order of fuel stations to be inspected. It is important to mention that each criterion is applicable only to 10% (ten percent) of the make fuel stations.

III. ANT COLONY OPTIMIZATION

The Ant Colony Optimization (ACO) [3] is based on real and solved problems by an ants' colony. This algorithm is a heuristic based on probability, created for solution of computational problems that involve search of ways in graphs. The ants' colonies are distributed systems that despite the individual simplicity represented in an isolated manner, the system's structure present a high leveled social organization [4].

The main functions executed by an ants' colony between the relationships among the ants include: building or increasing the nest, finding food, feeding the brood [5].

On the interactions between ants searching for food and building trails, a substance called pheromone is used. This substance influences the ants in the choice of innumerous routes, in other words, how much more the tax concentration of pheromone in a certain way, the biggest will be the chances for an ant to choose the same way [6].

The main characteristics are:

- The ants' population (agents) is an independent being moving around simultaneously without a central control.
- The search for routes happens in a deterministic way.
- The algorithm is cooperative, namely, each ant chooses a way based on the pheromone's concentration deposited by other ants.

The algorithm main idea is the indirect communication based on the pheromones routes between an agents' colony called ants [7]. The mains mathematical formulations that compound the algorithm are described below.

The equation (1) illustrates the mathematical formulation used on the work for the ants' colony algorithm [8] for indicate a probability of ant κ in this point i and choice point j:

$$p_{ij}^{k}(t) = \begin{cases} \frac{[\tau_{ij}(t)]^{\alpha} \cdot [\eta_{ij}]^{\beta}}{\sum [\tau_{ij}(t)]^{\alpha} \cdot [\eta_{ij}]^{\beta}} \\ \kappa \in allowed_{\kappa} \\ 0, others\ cases \end{cases} \quad (1)$$

On the equation (1), the variable α is a weighting of the pheromone $(0 \leq \alpha \leq 1)$ and β is the a weighting of the heuristic information $(0 \leq \beta \leq 1)$, where $\eta_{ij} = 1/d_{ij}$ is the visibility between the variables i and j.

The equation (2) shows the formulation that defines the pheromone deposited on the route [8]:

$$\Delta\tau_{ij}^{k} = \begin{cases} \frac{Q}{L_k}, if\ the\ \kappa - th\ ant\ use\ the\ track\ (i,j) \\ 0, others\ cases \end{cases} \quad (2)$$

The variables that compound equation (2) are defined as follows:

- Q is a project constant.
- L_k is the length of the circuit of the κ-th ant.

When an ant finishes the circuit in a $t_0, t_0 + n$ time and consists in a cycle of n interactions, the equation result is used to update the amount of substance deposited on the route, based on equation (3) [8].

$$\tau_{ij}^{k}(t+n) = \rho \cdot \tau_{ij}^{k}(t) + \Delta\tau_{ij}^{k} \quad (3)$$

On equation (3), the variable ρ represents the route's persistence during the cycle $(0 \leq \rho \leq 1)$, in which the value $(1-\rho)$ the trail evaporation between the field and the t and $t+n$.

This way, the algorithm ACO searches for a feasible solution for the famous Travelling Salesman Problem (TSP), it is a problem that belongs to the category NP-Hard from complexity exponential [4]. Traveler simulating an ants' walk by a graph using the mathematical modeling for the concentration of pheromone in the graph [9]. However, the ACO algorithm does not guarantee the best way but a good solution with polynomial execution cost.

IV. RELATED WORK

The TSP is of importance since similar combinatorial optimization problems arise in industrial applications and can be formulated as TSP-like instances [10].

In the business scenario, Google invests in solutions to the TSP through the routes services available in the Google Maps API V3. By default, the routes service calculates a path which includes the reference points provided in the indicated order. Optionally, the routes service may optimize the path provided by rearranging the points of reference in a more effective order [11].

However, the routes service offered free by Google Maps API V3, have some limitations in regard the amount of allowed points restricting to a total of eight points. Moreover, the API does not offers directly the insert of new criterions for the creation of the path.

The application S-route uses the Google Maps API only in georeferencing services and applies the ACO approach for route optimization that allows the use of up to 60 tested points. Another S-Route differential, is presente in the possibility of developing routes based on criterions such as fuel quality and documentation**.**

V. PROPOSED SYSTEM

The prototype s-Rota aims to automatize part of the fuel samples' collection process of LAPQAP. So, the procedures executed by the LAPQAP are analyzed aiming to absorb and understand its main features.

A. S-Rota modeling

In order to make the visualization of the activities' diagram from the Figure 2, the activities' diagram shown in Figure 2 has been used. This activities' diagram is a generalization.

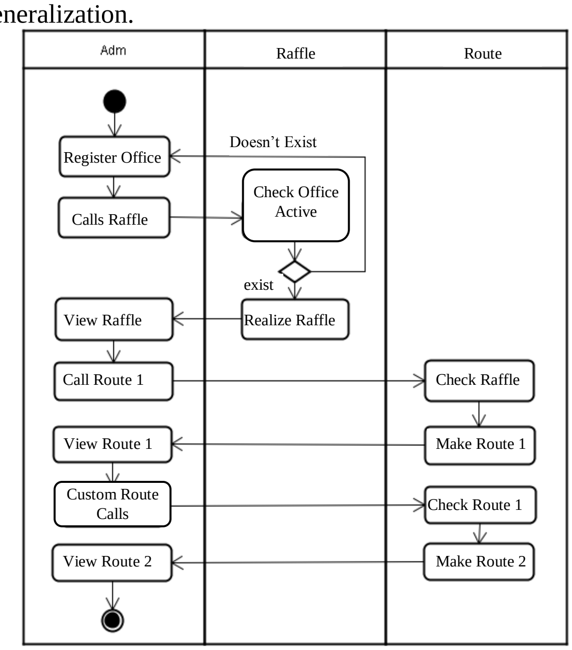

Figure 2. Activities' Diagram.

Figure 2 is a generalization, called, a general summary of the routes' creation process by the prototype. The stage starts with the administrator enrolling the existing fuel stations and requiring the lottery or assortment in execution.

Before that phase, the existence of stations in the data base is checked; if there are stations, the raffle is done and sent to the administrator. Then the routes definition process is started by the user.

After the prototype search for the last raffle done and elaborates the route based on the distance called rota1, that is, at this moment the shorter a total route is, the better. After the router 1 is elaborated, the administrator asks for the elaboration of personalized route called router 2. The activities' diagram finishes with the visualization of router 2 by the administrator.

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B. S-Rota Implementation

The S-Rota prototype has been implemented with the composition of the following elements:

- Web Server / S-Rota web application.
- Maps API .
- Data base manager system (SGBD).

The web server is responsible for storing and make it available on the net the S-Rota application, specifically on the Internet. The software is accessed as any conventional website. The languages used for the prototype of the application making were PHP [12] and Java Script [13].

For the maps API, it has been searched an API of maps that offers services dynamically geo-referred and without costs concerning software's license. An option to the approached criterion is Google Maps [11].

As the maps API uses Java Script, the applied searching algorithm has been developed in this language, to make the communication between the maps API and the prototype that uses data structure in XML format as well easier [14]. Besides the programming languages, the prototype stores the information recorded and generated by the application in a relational SGBD.

To manage the objective of each element listed by the LAPQAP, the project has defined the following development stages:

- Data maintenance.
- Fuel Stations Selection.
- Routes elaboration.

C. Data Keeping

This stage represents the data management inserted at the S-Rota. Such activities are related to the administrator profile. The main items in this process are:

- Fuel station.
- Collector.
- Note.

In the S-Rota prototype, the information regarding the item fuel station stores in the table called Fuel Station. These information work as feeding for the next stages of Fuel Stations selection and Routes elaboration.

Besides that, the table Fuel Station is related to other tables such as the fuel's quality (qualitycomb) and the table documentation (documentation). Through these relationships it is possible to associate the fuel station to the quality of each fuel traded and the documentation historical; such information are essential to the elaboration of the personalized route.

The next item, called collector, represents the responsible for collecting the fuel samples. The data of each responsible collector are stored in a table called collector; such information contains personal data and the historical of each collector regarding the each collection done.

In the last item (notes), the administrator inserts in the data bank any unexpected event in the collection process, in other word, in the table called reminder it is registered any unwanted event.

D. Fuel Stations' Selection

At this stage, the prototype should select in a random and transparent way the reseller fuels stations that will be inspected by the LAPQAP.

In this process, a class called SORTEIOCLASS has been projected with several functions, among them it is cited the function sorteio() (raffle). This function basically checks the data bank of the active fuel stations and then, the function array_rand [8], the fuel stations are organized randomly conforming the limited amount of fuel stations defined by the function countSorteio().

By the user watching, the administrator access the raffle screen and asks for the Fuel stations selection. Then, a file in XML format containing the information about the raffle fuel stations needed for the maps' generation is generated.

E. Routes Elaboration

For the routes elaboration, it is necessary in advance to have a map with the fuel station selected. The Google Maps' carry the API file having all the necessary information for the localization and identification of each fuel station and the starting point (UFMA). With these steps, the S-Rota is able to represent each item in the map generated by the API, finding them in the Maranhão State.

Figure 3 shows the elements geo-referred, such as: starting point and fuel stations present in the XML file.

Figure 3. Route's elaboration.

The API acts basically in the representation of geographical information and in the geo-referred data input for the search algorithm.

The responsibility of evaluating the better way is given to the search algorithm. In this case, the algorithm optimization applied to solve the Travelling Salesman Problem had as a base the ant's colony.

In this context, the mathematical principles and the concepts regarding the ant's colony have been implemented in Javascript aiming to interact with the Google Maps' API. The number of ants (n Ants) and of interactions used by the algorithm has been 10 each [4].

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In the following pseudo-code, the main function of the implementation of the ants' colony, the function ACO ( ) is represented.

```
function ACO(){
    Start the matrix of pheromone ;
    distAnts(nAnts); //'distributes the ants
    for i =0 to nIterations-1 then{
        for j=0 to nStation-1 then{
            for k=0 to nAnts-1 then{
                jSolution = generateRoutes(j);
                costSol=checkCost(jSolution);
                if(costSol < smallCost) then{
                    smallCost=costSol;
                }
            }
        }
        update_of_pheromone();
    }
```

In the pseudo-code, the function *generateRoutes(j)* represents the generation of the route executed by the ants which do by choosing the best points to follow the city *i* to *j* constructing the route according to equation (1). The function *update_of_pheromone()* represents the update of the matrix of pheromone that is carried through to each interactions *nInterations*, in which if increases or decreases the variable τ_{ij} (nivel of pheromone between *i* and *j* according to equation (3).

The following stage is the definition of the course of the personalized route. The process that establishes the new sequence of priorities between the fuel stations, analyzing the distance, fuel's quality and documentation criterion, conforming cited previously.

So, the new scoring of the fuel stations is obtained by an average of the three criteria, conforming the equation (4):

$$\frac{D \times P_D + C \times P_C + D_o \times P_{Do}}{P_D + P_C + P_{Do}}, \quad (4)$$

In which the variables are:

- D is the scoring of the fuel stations based on the distance.
- P_D is the weight defined by the administrator for the distance.
- C is the scoring of the fuel station based on the fuel quality.
- P_C is the weight defined by the administrator for the fuel's quality.
- D_o is the scoring of the fuel station based on the documentation.
- P_{Do} is the weight defined by the administrator for the documentation.

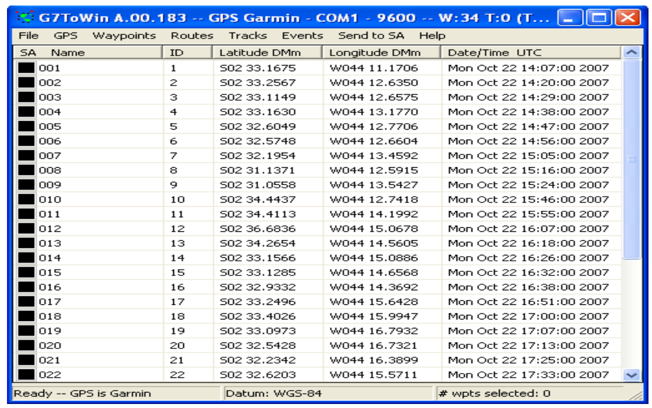
The variable scoring D, C *and* D_o may vary between the values from 0 to 100. For the scoring of C, in which the fuel station is irregular, in only one type of fuel, the scoring received is 33, for two types 66 and for three types 100. For the scoring of D_o , either is 0 for the irregular fuel station or 100 for the regular fuel station.

The weights are defined by the administrator through the prototype. Thus, the user may establish a priority order for each criterion according to the administrator needs.

F. Results

To get the prototype validation process started S-Rota, the LAPQAP provide real data referring to the collection done on October 22nd, 2007. The data extraction happened by the application G7ToWin version A.00.183.

The application carries the data obtained by the GPS Garmin that furnishes the geo-referred coordinates of each collected fuel station. The fields used for the results comparison were Fuel Station, Latitude, Longitude and Date/Time of the Collection as per figure 4.



SA Name	ID	Latitude DMm	Longitude DMm	Date/Time UTC
001	1	S02 33.1675	W044 11.1706	Mon Oct 22 14:07:00 2007
002	2	S02 33.2567	W044 12.6350	Mon Oct 22 14:20:00 2007
003	3	S02 33.1149	W044 12.6575	Mon Oct 22 14:29:00 2007
004	4	S02 33.1630	W044 13.1770	Mon Oct 22 14:38:00 2007
005	5	S02 32.6049	W044 12.7706	Mon Oct 22 14:47:00 2007
006	6	S02 32.5748	W044 12.6604	Mon Oct 22 14:56:00 2007
007	7	S02 32.1954	W044 13.4592	Mon Oct 22 15:05:00 2007
008	8	S02 31.1371	W044 12.5915	Mon Oct 22 15:16:00 2007
009	9	S02 31.0558	W044 13.5427	Mon Oct 22 15:24:00 2007
010	10	S02 34.4437	W044 12.7418	Mon Oct 22 15:46:00 2007
011	11	S02 34.4113	W044 14.1992	Mon Oct 22 15:55:00 2007
012	12	S02 36.6836	W044 15.0678	Mon Oct 22 16:07:00 2007
013	13	S02 34.2654	W044 14.5605	Mon Oct 22 16:18:00 2007
014	14	S02 33.1566	W044 15.0886	Mon Oct 22 16:26:00 2007
015	15	S02 33.1285	W044 14.6568	Mon Oct 22 16:32:00 2007
016	16	S02 32.9332	W044 14.3692	Mon Oct 22 16:38:00 2007
017	17	S02 33.2496	W044 15.6428	Mon Oct 22 16:51:00 2007
018	18	S02 33.4026	W044 15.9947	Mon Oct 22 17:00:00 2007
019	19	S02 33.0973	W044 16.7932	Mon Oct 22 17:07:00 2007
020	20	S02 32.5428	W044 16.7321	Mon Oct 22 17:13:00 2007
021	21	S02 32.2342	W044 16.3899	Mon Oct 22 17:25:00 2007
022	22	S02 32.6203	W044 15.5711	Mon Oct 22 17:33:00 2007

Figure 4. G7ToWin Data.

By the field Date/Time of the Collection it is possible to determine the sequence of visited fuel station in the time by the LAPQAP, which allows the route done by the driver to be traced. For the visualization of this course it was used the Google Maps, as per figure 5.

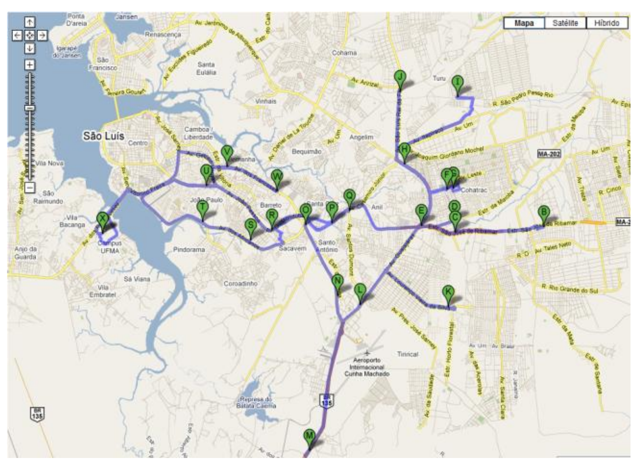


Figure 5. ANP Driver's route

The course done in figure 5 resulted in a total way of 85,49km. The elaboration of this route is done in an empirical way by the driver, not having a specific standard.

For the elaboration of the course by the prototype S-Rota, the following premises gave been considered:

- The variables $P_C = 0$ and $D_o = 0$.
- The same points of the last experiment as per figure 4.

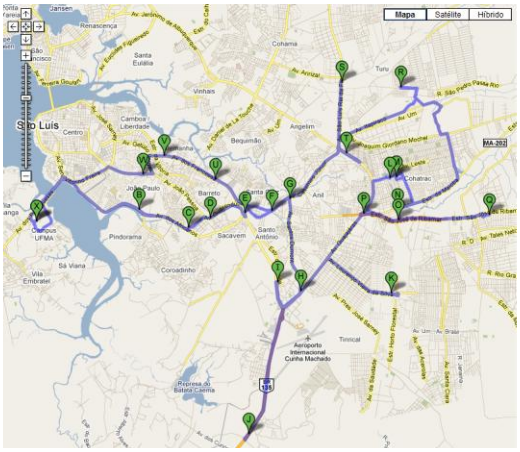


Figure 6. S-Rota's route.

The course elaborated by the prototype S-Rota resulted in a way of 77.48km. The difference between the figure 5 and the figure 6 is of 8.01 km.

The prototype accomplished the operation faster which has brought an economy of approximately 9.37% comparing to what accomplished the driver elaborating the route handmade.

VI. Conclusion

This research has presented a prototype that searches for the best way for the Fuel Samples' Collection stage. As a complement of this prototype called S-Rota, an optimization algorithm based on the optimization approach of ants' colony [7] has been developed, adapted to the language Javascript, applied to Google Maps' API and integrated to the S-Route base.

The prototype gathered with the optimization algorithm of ants' colony aims to automatize part of the process of Fuel Samples' Collection approaching concepts related to the UFMA's Analysis and Research in Petrol Analytical Chemistry Laboratory needs. It also creates the fuel stations in a random way, selecting a percentage by the user of active and existing fuel stations in the data base. This way, any inappropriate tendency in the fuel stations selection is avoided.

Despite the satisfactory and positive acquisition in this piece of work, some points still present limitations. As an example, the searching algorithm has not been tested in big fuel stations net yet and besides that does not evaluate the highways conditions and the traffic level. In these conditions, it is wished to improve the searching algorithm, in order to ascertain good results in big fuel stations nets.

This paper applied the Classic ACO for prove this code with minimal conditions its can resolved with success the problems best way for the S- Rota Software.

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